

# Trilobite-constrained Ordovician Biogeography of China with Reference to Faunal Connections with Australia

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All the plates and most of the terranes in China exhibit close biogeographic links and may have formed part of eastern Peri-Gondwana during the Ordovician. Synthetic analysis based largely on the platform/inner shelf trilobite faunas suggests that the Chinese eastern Peri-Gondwanan plates and terranes may have belonged to a single biogeographic province during the Tremadocian (Tremadoc) and late Katian-Hirnantian (Ashgill), but may be separated into two sub-provinces during the Floian-early Katian (Arenig-Caradoc): one consists of South China, Tarim and Annamia, and the other may include North China, Sibumasu, Southern Tibet, Tianshan-Beishan and possibly Hainan. However, the deep-water facies trilobites of the relevant Chinese geographic units had progressively become more unified from the mid Darriwilian to early Katian (Llanvirn to Caradoc) before the sub-provinces eventually broke down by the late Katian (Ashgill). Australian Ordovician trilobite faunas had close affinities with most of the Chinese eastern Peri-Gondwanan plates and terranes, but closest biogeographic links were in particular with North China and Middle Tianshan-Beishan.

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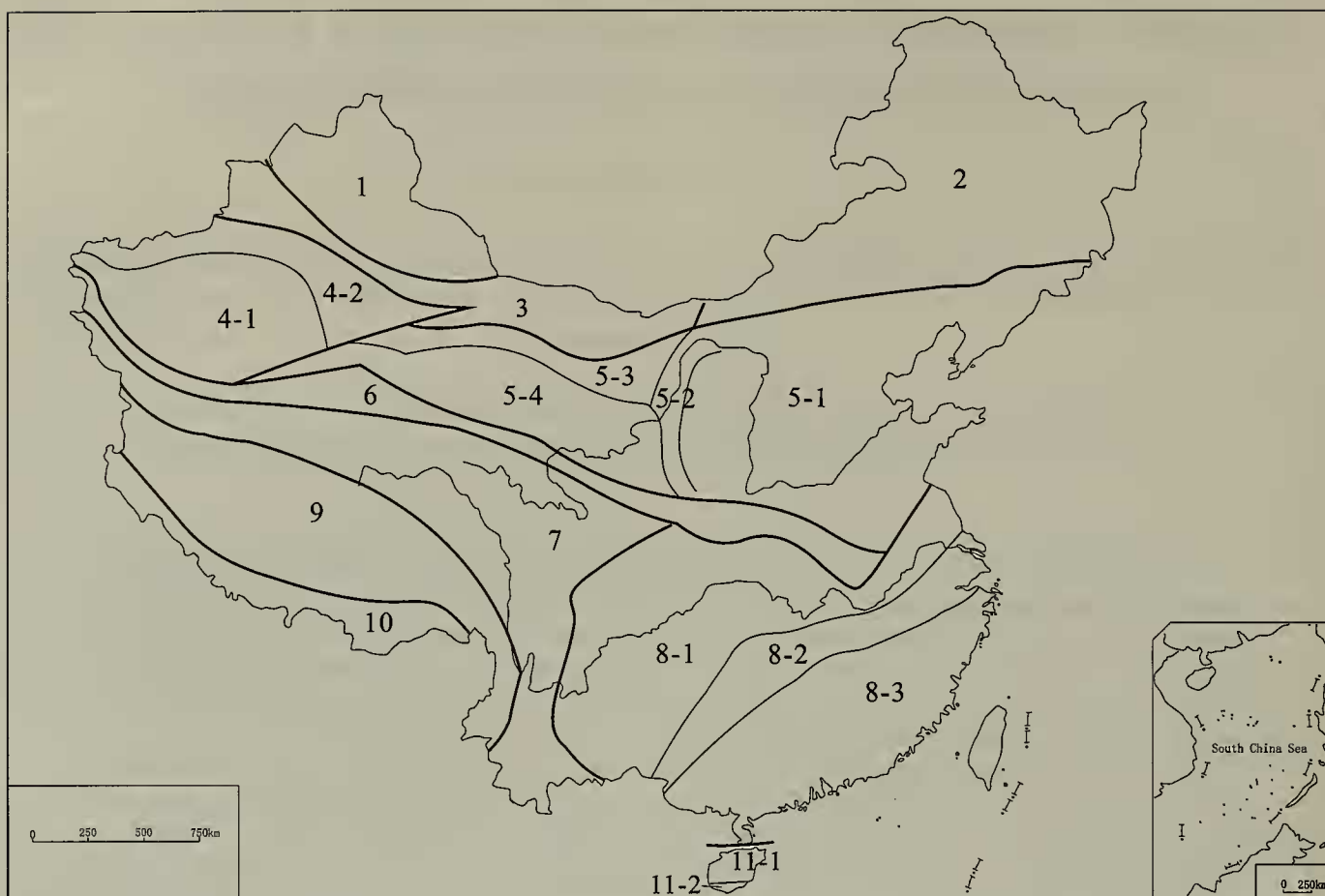
## INTRODUCTION

Eleven Chinese Ordovician geographic units, corresponding mainly to different allochthonous continental masses (plates and terranes), are divided largely on the basis of evidence from regional tectonics, palaeogeography and stratigraphy (Fig. 1). Units or regions now in close proximity were distantly separated from each other during the Early Palaeozoic, and the assembly of those landmasses likely underwent a long-sustained process that extended from the Late Carboniferous to Cenozoic (Zhou et al. 2007). However, trilobite evidence indicates that all the plates and most of the terranes (with exceptions noted below) in China exhibit close biogeographic links to each other and may have formed part of eastern Peri-Gondwana during the Ordovician (e. g. Zhou and Dean 1989; Webby et al. 2000; Fortey and Cocks 2003). Terranes where trilobite faunas show a strong affinity with those of Siberia and Laurentia include the Altay Terrane of the Northern Xinjiang Region (part of the mobile zone between the Siberia and Tarim plates) (region 1 in Fig. 1) and the Ergen-

Hinggan Terrane of the Hinggan Region (mobile zone between the Siberia and North China plates) (region 2 in Fig. 1). The Late Ordovician record of *Calyptaulax* and *Isotelus* in the Altay Terrane (respectively described by Zhang (1981) as *Calliops taimyricus* Balashova and *Fuyunia junggarensis* Hsiang and Zhang; see Zhou et al. 1996a) supports this affinity. Occurrences of Mid and Late Ordovician forms such as *Parasphaerexochus*, *Pliomerellus*, *Quinquecosta* (see Zhao et al. 1997), *Cybelurus* (see Xiang and Mao 1986), *Eorobergia* (see Xiang and Mao 1986, as *?Kainella* sp.), *Cybeloides*, *Calyptaulax*, *Isotelus* (see Nan 1985), and the monorakids *Ceratoevenkaspis* and *Isalauxina* (Zhou Zhiyi unpublished collection) in the Ergen-Hinggan Terrane also indicate strong links with Siberia and Laurentia.

In this paper, biogeographic links among the Chinese plates and terranes of northeastern Peri-Gondwana are further reviewed on the basis of a complete dataset available for the Ordovician trilobite record in China (Zhou and Zhen, in press). As indicated by Fortey (1975), Fortey and Owens (1978), Zhou et al. (1989, 1990, 1992) and Fortey and Cocks (2003), trilobites usually show decreased endemism

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**Figure 1. Map showing Ordovician geographic units of China (after Zhou et al. 2007). 1. Northern Xinjiang Region (part of the mobile zone between the Siberia and Tarim plates). 2. Hinggan Region (mobile zone between the Siberia and North China plates). 3. Middle Tianshan-Beishan Region (part of the Kazakhstan Mid Plate). 4. Tarim Region: 4-1, Bachu-Kalpın Area (the Tarim Block proper, developed with platform facies (Tremadocian-Dapingian or Tremadoc-late Arenig) and shallow outer shelf facies (early Darriwilian-early Katian or latest Arenig-Caradoc); its northern boundary employed here is suitable for the Tremadocian-Dapingian only (see Zhou et al. 1990, 1992); and 4-2, Southern Tianshan Area (deep-outer-shelf basin or trough fringing the northern margin of the Tarim Block) (Zhou et al. 1995a, 1996a; Ni et al. 2001). 5. North China Region: 5-1, Yellow River Area (North China Platform); 5-2, Ordos Area (western marginal area of the platform during the early Darriwilian-late Katian or latest Arenig-early Ashgill, see Zhou et al. 1989); 5-3, Dunhuang-Alexa Area (a dislocated old land lacking Early Palaeozoic deposits, possibly derived from the northern margin of the North China Platform, see Zhou et al. 1996a); and 5-4, Qaidam-Qilian Area (consisting of the Qaidam and Middle Qilian terranes and the Altun faulted block, see Zhou et al. 1996a). 6. Kunlun-Qinling Region (polycyclic orogenic belt that crosses over the mainland of China). 7. Northern Qiangtang-Simao Region (a northern extension of the Indochina Terrane, see Zhou et al. 1998a, 2001a). 8. South China Region: 8-1, Yangtze Area (inner shelf/platform); 8-2, Jiangnan Area (outer-shelf slope; note its northern boundary varied in the different time intervals due to facies shifting, and that employed herein is suitable for the Tremadocian only, see MK Zhou et al. 1993, fig. 4-1); and 8-3, Cathaysia Area (off-shelf basin) (MK Zhou et al. 1993) (or Pearl River Area, see Lu et al. 1976). 9. Baoshan-northern Tibet Region (a northern extension of the Sibumasu Terrane, see Zhou et al. 1998a, 2001a). 10. Southern Tibet Region (part of the India Plate, see Fan et al. 1994). 11. Hainan Region (area subdivision see Wang 1989): 11-1, Wuzhishan Area (deduced as a mobile zone that edged the shelf); and 11-2, Sanya Area (shelf).**

from the onshore towards offshore biofacies belts in a plate or terrane, and those elements which are endemic to a particular plate or plates are the most important indicators in defining biogeographic units.

Therefore, in the following discussion the platform/inner shelf faunas (especially endemic trilobites) are emphasized, although, as indicated by Zhou and Dean (1989), a few endemics restricted to the deep-



water facies are also significant enough for defining faunal provinces.

#### EASTERN PERI-GONDWANAN TERRANES

Ordovician trilobites are only sporadically documented in a number of Peri-Gondwanan terranes in China, where the framework of biofacies differentiation either in space or in time is usually poorly known. Therefore, their biogeographic relationships to the related geographic units or plates are only briefly discussed herein based on the rather incomplete faunal data, chiefly those recorded from shallow marine successions.

*Middle Tianshan-Beishan Region/Terrane* (part of the Kazakhstan Mid Plate) (region 3 in Fig. 1): The only inner-shelf trilobite fauna of the Sandbian to early Katian (Caradoc) age was described from Ejin Banner, western Inner Mongolia (Zhou and Zhou 2006). The dominant forms in this fauna, such as *Bulbaspis*, *Collis*, *Pliomerina*, *Sinocybele* and *Basilicus* (*Basiliella*), are also extremely diverse in the coeval fauna of Kazakhstan, especially of the Chu-Ili Terrane (see Fortey and Cocks 2003), and they even share a number of taxa at species level. The region also has close biogeographic links to the North China Plate, where coetaneous shallow-water associations characterized by *Pliomerina* and *Basilicus* (*s.l.*) were recorded from the Altun Mountains, eastern Xinjiang (5-4) (Zhou et al. 1995b) and southern Ningxia and central Shaanxi (5-1) (Zhou et al. 1982). However, a deeper-water trilobite fauna of Sandbian-early Katian age reported from northernmost Tarim (Zhang 1981) includes *Bulbaspis*, *Sinocybele* and *Basilicus* (*Basiliella*), and also exhibits a faunal affinity with this Kazakhstan fauna. Genera in common with the inshore sites of eastern Australia (Webby 1971; Edgecombe et al. 1999a, 2004; Edgecombe and Webby 2006), such as *Pliomerina*, *Sinocybele* and *Basilicus* (*Basiliella*), are indicative of a biogeographically significant faunal province (Webby 1987; Webby et al. 2000).

*Hainan Region/Terrane* (region 11 in Fig. 1): Only a few outer-shelf-facies trilobites were reported from the Late Ordovician in the Sanya area (Zeng et al. 1992), of which the genera of a Sandbian to early Katian age including *Ampyxinella*, *Birmanites*, *Dionide* and *Bulbaspis* were mostly widespread forms. As deep-water faunas of the Tarim and South and North China plates had already become uniform in composition during the Sandbian to early Katian (Fig. 2D), their biogeographic affinities with the regions in

question are difficult to affirm, but *Bulbaspis* alone may suggest a faunal link with the Middle Tianshan-Beishan Terrane and even with the Tarim Plate.

*Southern Tibet Region* (part of the India Plate) (region 10 in Fig. 1): Only a few trilobites of the Floian to early Darriwilian (Arenig) age are known, including *Basilicus* (*Basilicus*) (as *Isoteloides bolingensis*), *Hystricurus* and *Pliomerina* (as *Ngaricephalus*) from Ngari, southwestern Tibet (Yang 1990) and *Pseudocalymene* (as *Eucalymene tuberculata*) from Nyalam of Mount Qomolangma (Chien 1976). All the trilobite taxa recorded in this region also occur in the coeval faunas of the North China Plate, where the genus *Pseudocalymene* is associated, as at Nyalam, with the nautiloid *Pomphoceras*, which is an element typical of the Yellow River Fauna (Chen et al. 1984).

*Baoshan-northern Tibet Region/Terrane* (a northern extension of the Sibumasu Terrane) (region 9 in Fig. 1): Late Ordovician trilobites have been described from the rocks of the Pagoda facies (Lindström et al. 1991) in southern Thailand (Fortey 1997) and westernmost Yunnan (Sheng 1974), representing a relatively widespread fauna of the deep-water-biofacies, with some forms being identical even at species level with taxa from South China (Fortey and Cocks 1998). However, the mid-late Darriwilian (Llanvirn) fauna from the inner-shelf-facies (Reed 1917; Sheng 1974) in the Baoshan area seems to be a mixture of trilobites exhibiting two different biogeographical affinities, with *Basilicus* (*Basilicus*) and *Pliomerina* typical of the contemporaneous fauna of North China, and with *Hexacopyge*, *Neseuretus*, *Prionicheilus*, *Reedocalymene*, and *Sinocybele* found in South China. Therefore, there remain ambiguities in the explanations for the alignment of this Cimmerian terrane. Fortey and Cocks (1998, 2003) favoured its close biogeographic and physical proximity to South China. However, Zhou et al. (1998a) preferred the reconstructions proposed by Scotese and McKerrow (1991) and Metcalfe (1992), in which the West Malaysia-Thailand Peninsula was located close to the North China Plate on the palaeo-equator, while Shan State and the Baoshan-northern Tibet Region may have been sited in a low latitudinal zone not far from the South China Plate.

*Northern Qiangtang-Simao Region* (a northern extension of the Indochina or Annamia Terrane) (region 7 in Fig. 1): The Tremadocian-early Floian shallow-water trilobites from Karakorum, southwestern Xinjiang include *Neopsilocephalina*, *Psilocephalina*, *Psilocephalops* and *Songtaoia* (as *Yinjiangia karakolumensis*) described by Zhang (1991), and *Asaphopsoides* (as *Asaphus elegantulus*; see Jell and Stait 1985) by Gortani (1934). A

less diverse Dapingian-early Darriwilian (late Arenig) inner-shelf fauna, comprising *Hungiodes*, *Liomegalaspides*, *Neseuretus* and *Ogyginus*, was recorded from Dali, western Yunnan (Zhou et al. 1998a), and *Neseuretus* and *Aristocalymene* (as *Neseuretus muliensis*; see Turvey 2005b) were described from Muli, southwestern Sichuan (Lee 1978). Most of the components are in common with the Yangtze platform, demonstrating a very close faunal link that existed between this Cimmerian terrane and the South China Plate. However, occurrences of *Asaphopsoides*, *Neseuretus* and especially *Ogyginus* indicate a western Gondwanan and Peri-Gondwanan faunal affinity, and suggest that the Annamia Terrane may have been located at higher latitudes or in a more westerly position as compared with the South China Plate (Zhou et al. 1998a; Fortey and Cocks 2003).

#### EASTERN PERI-GONDWANAN PLATES

Ordovician trilobites are well recorded in three cratonic plates: the South China Plate (region 8 in Fig. 1) [including also the Wudang or South Qinling Terrane (see Yang 1988; Shang et al. 1994) of the Kunlun-Qinling Region (region 6 in Fig. 1) – a polycyclic orogenic belt that crosses over the mainland of China], North China Plate (region 5 in Fig. 1) [including also West Kunlun, a displaced landmass of the North China Plate proper (Zhou et al. 1996a), now located on the western end of the Kunlun-Qinling Region; the Qaidam and Middle Qilian terranes and the Altun faulted block (area 5-4 in Fig. 1) (see Zhou et al. 1996a)] and Tarim Plate (region 4 in Fig. 1). All of them were largely situated in low latitude zones during the Ordovician (Cocks and Torsvik 2002; Webby et al. 2000; Turvey 2005a). In each plate, trilobite faunas display a progressive onshore to offshore transition in composition and diversity. Ecological differentiation of the faunas and their response to biofacies has been documented along environmental gradients from west to east and from south to north (platform/inner shelf to off-shelf basin) of South China (Zhou et al. 1999, 2000, 2001b, 2003, 2004; Z.Q. Zhou et al. 2000; Yuan et al. 2000; Turvey and Zhou 2002, 2004a, 2004b; Yin et al. 2000; Turvey 2005a), from east to west (platform to shallow-outer-shelf basin) of North China (Zhou et al. 1989) and from south to north (platform to deep-outer-shelf basin/trough) of Tarim (Zhou et al. 1990, 1992). Accordingly, Tremadocian-early Katian trilobites of the inner shelf/platform and outer shelf/slope from each of the plates are separately listed in the Appendix, except for those of the Qaidam-Qilian

terranes (area 5-4 in Fig. 1), as the biofacies patterns in these areas are not well established yet. They bear mainly deeper-water forms, but also include a few shallow-water genera.

Early studies indicated that, as a whole, the respective trilobite faunas of the South China and North China plates were closely comparable in the Tremadocian, but became distinct from each other afterwards (Zhou and Fortey 1986), while those from the Tarim Plate mostly extended their distribution into the South China Plate throughout the Ordovician, suggesting that both were closely situated palaeogeographically (Zhou and Chen 1990, p. iv; 1992, p. ii; Zhou et al. 1996a, pp. 11, 20). This view is supported by a further comparison among the inner shelf/platform faunas of the three plates; those trilobites with significant biogeographical implications are further reviewed herein.

Tremadocian trilobite faunas of North China are characterized by having distinctive endemics – *Koraipsis* and *Penchiopsis*, in addition to a few bathyurids, and those of South China by having *Dactylocephalus*, *Tungtzuella* and *Psilocephalina*. However, most of the other trilobites from both plates are in common, such as *Chosenia*, *Songtaoia*, *Wanliangtingia* and *Yosimuraspis*. It is interesting to note that some trilobites typical of either of the two plates co-occur in the contemporaneous faunas of Australia and northern Iran (the Alborz Terrane). The Tremadocian trilobites described from the latter area by Bruton et al. (2004) and Ghobadi Pour (2006) include *Asaphellus inflatus* Lu, *Psilocephalina lubrica* Hsu, *Dactylocephalus*, *Kayseraspis*, *Peltabellia*, and *Iliaenus hinomotoensis* Kobayashi. The occurrence of the first three suggests a close link to South China, and the others are common elements of the North China faunas. In Australia, Shergold (1991) reported *Asaphellus* cf. *trinodosus* Chang, *Koraipsis*, *Kayseraspis* and *Psilocephalina* cf. *lubrica* Hsu from the northern part of the Amadeus Basin, Jell and Stait (1985) described *Asaphellus* cf. *trinodosus* Chang, *Asaphopsoides*, *Chosenia*, *Dikelokephalina asiatica* Kobayashi, and *Hystericurus penchiensis* Lu from Tasmania, and Laurie and Shergold (1996) recorded *Penchiopsis* from the Canning Basin. These trilobite records show a remarkable similarity to those of North China, but a close link with South China also existed at either specific or generic rank, as indicated by the occurrence of *Psilocephalina* cf. *lubrica* Hsu, *Asaphopsoides* and *Chosenia*.

From the Floian to early Katian (Arenig-Caradoc), trilobite faunas of North China with endemic forms like *Eoisotelus*, *Lonchobasilicus* and *Pliomerina*, in addition to variety of species of *Basilicus* (*s.l.*), are



quite distinct from those of South China, which are characterized by having *Birmanites*, *Calymenesun*, *Fenghuangchengia*, *Hexacopyge*, *Liomegalaspides*, *Meitanopsis*, *Mioptychopyge*, *Ningkianites*, *Omeipsis* and *Taihungshania*. The faunal differences may imply a significant biogeographical separation between these two plates. Among the Floian-Darriwilian (Arenig-Llanvirn) trilobites, *Prosopiscus* was widely distributed in Australia, South and North China, Sibumasu, Himalayas and Argentine Precordillera, being of important biogeographic significance (Webby et al. 2000; Paterson 2004). As indicated by Paterson (2004), the genus originated in the early Floian of Australia, but its early species, *P. lauriei* Paterson from northwestern New South Wales, is closely related to *P. magicus* Zhou from the North China Plate. Webby (1971, 1974, 1985, 1987, 1992) and Webby et al. (2000) suggested a biogeographically distinctive *Eokosovopeltis-Pliomerina* Province in the Caradoc (Sandbian to early Katian) to cover part of the eastern Peri-Gondwanan regions, including East Australia, East Asia and Kazakhstan, and probably the Argentine Precordillera (Edgecombe et al. 1999b). However, the eponymous forms *Eokosovopeltis* and *Pliomerina* recorded from New South Wales (Webby 1971, 1974; Edgecombe and Webby 2007) and Tasmania (Corbett and Banks 1974; Edgecombe et al. 1999, 2004) were lacking in all the geographic units of East Asia during the Sandbian to early Katian, except the North China Plate, where, as mentioned above, *Pliomerina* occurs though with no *Eokosovopeltis* associated. A few deeper water taxa with more restricted distribution including the distinctive three-segmented raphiophorid genus *Nanshanaspis* are also in common between the Qaidam-Qilian Area (5-4 in Fig. 1) (Chang and Fan 1960; Zhou et al. 1995b) and southern Tasmania (Burrett et al. 1983), suggestive again of strong biogeographic relationships between Australia and North China. Though as noted by Webby et al. (2000), faunal links based on the available biotic data from Australia were in general with the Chinese plates, it is more likely that Australian trilobite faunas had closest affinities with those of North China during the Floian-early Katian.

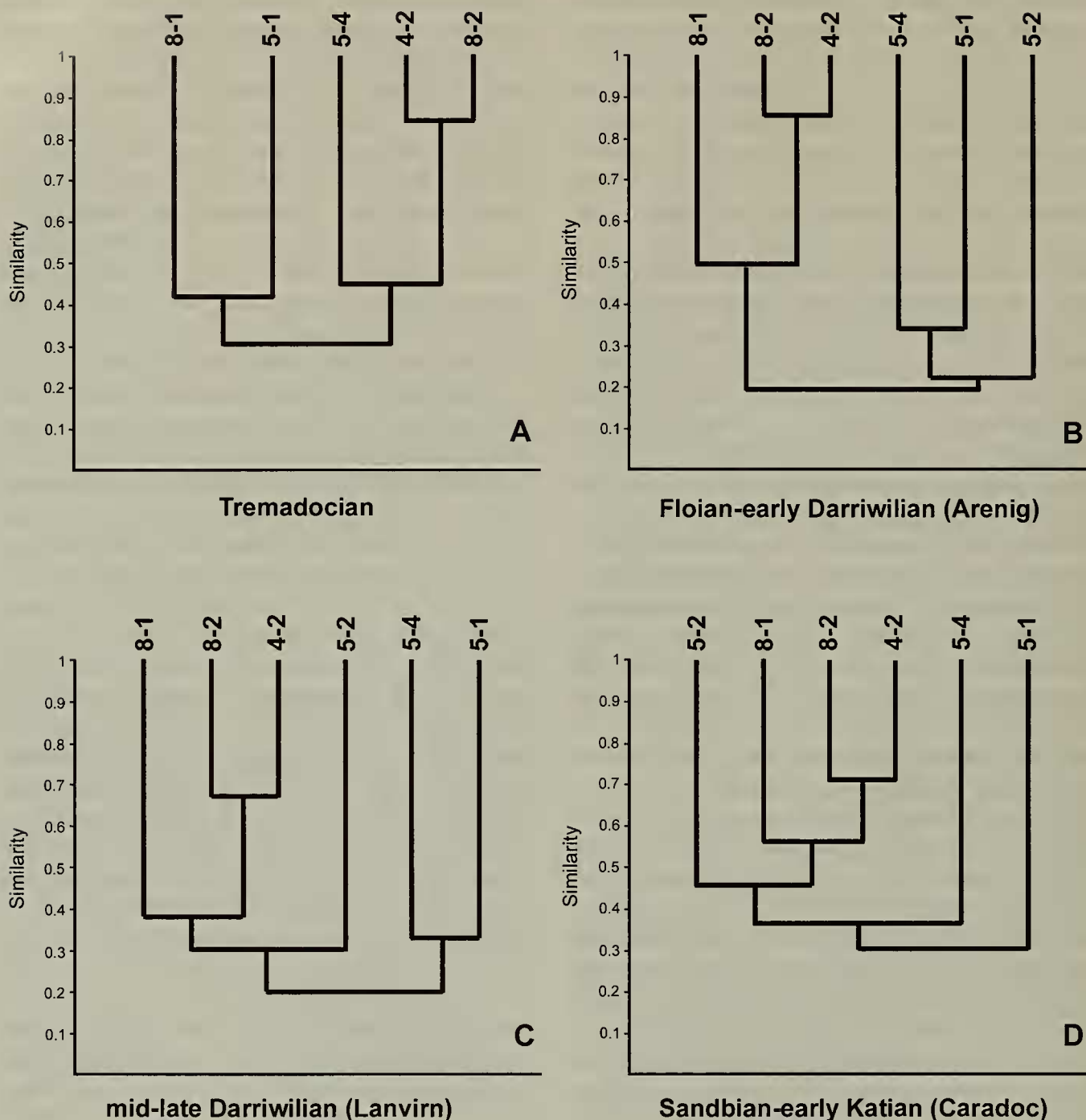
In Tarim, only a bathyurid *Aksuaspis* is recorded in the Tremadocian dolomite at Kalpin (Zhou et al. 1998c), but the occurrence of a few trilobites, including *Asaphopsoidea*, *Paraszechuanella* [= *Pseudocalymene*, see Bruton et al. 2004], and *Psilocephalina* described by Zhou (see Lin et al. 1990) from a shallow outer shelf Nileid Biofacies at Uligezhitag (Zhou et al. 1990, 1992) suggests a close faunal link with South China. From the Floian onwards, the shallow-water trilobites were all associated with

carbonate buildups, and have been proved to be of worldwide distribution, except for *Liomegalaspides*, a Floian-early Darriwilian form typical of the coeval fauna in South China, which was described from the platform facies of Tarim (Zhou et al. 1998c, as *Megalaspides angustus* and *M. sp.*). However, there was also developed a unique provincial link with the South China Plate, as evidenced by the occurrence of a number of common shallow outer shelf elements, of which characteristic forms are *Calymenesun*, *Mioptychopyge*, *Reedocalymene*, *Xiushuilithus*, *Yanhaoia* and *Zhenganites* (see Zhang 1981; Zhou et al. 1990, 1992, 1998b; Yuan and Zhou 1997).

The late Katian (early-mid Ashgill) inner shelf/platform trilobite faunas are almost lacking in China, with the exception of a few forms that were reported from the latest Katian (mid-Ashgill) carbonate buildups in the eastern margin of the Jiangnan Area (Zhou et al. 2004). Occurrence of the *Nankinolithus* fauna from the deeper sites (areas 4-2, 5-2, and 8-2, see Fig. 1) may, however, suggest that the faunal connection between the South China-Tarim and North China plates became closer again during this time interval. Comparatively uniform patterns of provincialism might continue to exist during the Hirnantian, when there were only a few trilobites (largely immigrants from high-latitude Gondwana) occurring in the Chinese plates, comprising *Dalmanitina* (*Songxites*) (in areas 4-1, 5-4 and region 8, see Fig. 1), *Eoleonaspis* (in area 5-4 and region 8), *Platycoryphe* (in area 5-4 and region 8), *Niuchangella* (in area 4-1 and region 8) and *Solariproetus* (in area 5-4).

In order to express the preliminary observations more clearly, cluster analysis of biogeographic links on the basis of trilobite genera (see Appendix) from four time intervals respectively (Tremadocian, Floian-early Darriwilian, mid-late Darriwilian and Sandbian-early Katian) was conducted using Simpson's coefficient (Fig. 2). It reveals that the Chinese plates belonged to a single biogeographic unit during the Tremadocian, and that their platform/inner-shelf and outer-shelf/slope facies areas can be separated into two distinct clusters (Fig. 2A), each of which shares a closely similar trilobite fauna. The Floian-early Darriwilian clusters (Fig. 2B) suggest that the South China-Tarim and North China plates may well be referred to two independent biogeographic units, as evidenced by different faunas distributed either in shallow or in deep sites. A similar pattern is also depicted by the mid-late Darriwilian (Fig. 2C) and Sandbian-early Katian (Fig. 2D) faunas, but deep-water facies trilobites of the North China Plate progressively become more analogous to those

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**Figure 2. Clusters of Ordovician geographic units on the basis of trilobite faunas (dataset see Appendix) using Simpson's coefficient, indicating the biogeographic affinities of Ordovician trilobites occurring in the shallow-water (4-1, 5-1, 8-1) and deep-water facies (4-2, 5-2, 5-4, 8-2) belts of Tarim (4), North China (5) and South China (8) plates (Fig. 1). A. Tremadocian; B. Floian-early Darriwilian (Arenig); C. mid-late Darriwilian (Llanvirn); D. Sandbian-early Katian (Caradoc). Note that only few Tremadocian and Floian-early Darriwilian platform trilobites were recorded from 4-1, which are not coded, and, as mentioned in the text, the coded trilobites from 5-4 are mainly deeper-water forms, but also mixed up with a few from shallow sites.**

of South China-Tarim. This suggests that a faunal exchange between offshore sites of both geographic units may have started long before the late Katian when the *Nankinolithus* fauna testifies to a shared biogeographic link amongst the Chinese plates.

### CONCLUSIONS

Trilobite evidence indicates that all the plates and most of the terranes in China exhibit a close biogeographic link and may have formed part of eastern Peri-Gondwana during the Ordovician, except



for the Altay Terrane of the Northern Xinjiang Region and the Ergen-Hinggan Terrane of the Hinggan Region, where trilobite faunas show a strong affinity with those of Siberia and Laurentia.

Well-defined biogeographic patterns are depicted mainly by the shallow-water components of the Ordovician trilobites, especially between the South China-Tarim and North China plates. Synthetic analysis suggests that all the Chinese eastern Peri-Gondwanan plates and terranes may be signified as belonging to a single biogeographic province during the Tremadocian and late Katian-Hirnantian, but exhibit significant faunal differences and therefore may be separated into two sub-provinces during the Floian-early Katian: one consists of South China, Tarim and Annamia, and the other may include North China, Sibumasu, Southern Tibet, Tianshan-Beishan and possibly Hainan. However, the deep-water facies trilobites of the relevant Chinese geographic units had progressively become more unified from the mid Darriwilian to early Katian before the sub-provinces eventually broke down by the late Katian.

Australian Ordovician trilobite faunas had close affinities with most of the Chinese eastern Peri-Gondwanan plates and terranes, but closest biogeographic links were in particular with North China and Middle Tianshan-Beishan.

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## APPENDIX

Based on the dataset compiled by Zhou and Zhen (in press), following are listed, in descending stratigraphic order, Ordovician trilobite genera that have been recorded from the inner shelf/platform (areas 4-1, 5-1, 8-1 in Fig. 1) and outer shelf/slope (areas 4-2, 5-2 and 8-2 in Fig. 1) of the Tarim, North and South China plates. The late Katian-Hirnantian (Ashgill) trilobites are excluded from the list, as the early Ashgill inner shelf/platform trilobite faunas are almost absent in China, and so are the early Darriwilian-early Katian (latest Arenig-Caradoc) shallow-water taxa from Tarim, because they were associated with carbonate buildups, and are cosmopolitan in distribution. The biofacies patterns are not well established yet in the Qaidam and Middle Qilian terranes and the Altun faulted block (area 5-4 in Fig. 1), but, judging from the faunal sequences and palaeogeographic framework (Zhou et al. 1996b, c), in addition to a few genera that may belong to the shallow-water dwellers, most of the listed trilobites were associated with slope facies. Note that the slope facies trilobites from the western marginal area (5-2 in Fig. 1) of the North China Platform occur only from the early Darriwilian onwards. Also only a few Sandbian-early Katian (Caradoc) offshelf pelagic trilobites were recorded in the Cathaysia Area (8-3 in Fig. 1) of South China, and most of them extended their distribution to the adjacent shelf slope (the Jiangnan Area, 8-2 in Fig. 1). Therefore, in the following list they are incorporated into the fauna of Area 8-2 (Fig. 1).

**Sandbian-early Katian (Caradoc)**

4-2: *Alceste*, *Amphilichas*, *Amphitryon*, *Ampyx*, *Ampyxinella*, *Basilicus* (*Basiliella*), *Birmanites*, *Bulbaspis*, *Calymenesun*, *Corrugatagnostus*, *Cyclopyge*, *Degamella*, *Dicranurus*, *Dionide*, *Dividuagnostus*, *Ellipsotaphrus*, *Endymionia*, *Illaenus*, *Kanlingia*, *Kongqiaoheia*, *Lisogolites*, *Lonchodomas*, *Microparia* (*Heterocyclopyge*), *Microparia* (*Microparia*), *Microparia* (*Quadratapyge*), *Nanshanaspis*, *Nileus*, *Ovalocephalus*, *Parisoceraurus*, *Penderia*, *Pricyclopyge*, *Pseudosphaerexochus*, *Reedocalymene*, *Remopleurides*, *Rhombampyx*, *Robergia*, *Sagavia*, *Scotoharpes*, *Shumardia*, *Sinocybele*, *Sphaerexochus*, *Stenopareia*, *Taklamakania*, *Telephina*, *Trinodus*, *Xiushuilithus*

5-1: *Basilicus* (*Basilicus*), *Lamproscutellum*, *Lonchobasilicus*, *Metopolichas*, *Pliomerina*, *Pseudostygina*, *Sphaerexochus*

5-2: *Birmanites*, *Chedaoia*, *Cyclopyge*, *Cyphoniscus*, *Geragnostus*, *Glaphurina*, *Kodymaspis*, *Lichas*, *Lisogolites*, *Lonchodomas*, *Microparia* (*Quadratapyge*), *Nileus*, *Ovalocephalus*, *Paraphillipsinella*, *Paratiresias*, *Phorocephala*, *Pliomerina*, *Pseudostygina*, *Rorringtonia*, *Shumardia*, *Sinocybele*, *Stenopareia*, *Telephina*, *Trinodus*, *Xenocybe*

5-4: *Ampyxinella*, *Basilicus* (*Basilicus*), *Corrugatagnostus*, *Cyclopyge*, *Elongatanileus*, *Endymionia*, *Hemiarges*, *Lonchobasilicus*, *Madygenia*, *Mendolaspis*, *Nanshanaspis*, *Nileus*, *Ovalocephalus*, *Pliomerina*, *Poronileus*, *Porterfieldia*, *Remopleurides*, *Rhombampyx*, *Shumardia*, *Taklamakania*, *Tarimella*, *Telephina*, *Toernquistia*, *Trinodus*, *Yumenaspis*

8-1: *Agerina*, *Amphilichas*, *Ampyx*, *Annamitella*, *Birmanites*, *Bumastoides*, *Calymenesun*, *Diacanthaspis*, *Dicranurus*, *Dulanaspis*, *Hexacopyge*, *Illaenus*, *Lamproscutellum*, *Lonchodomas*, *Metopolichas*, *Ovalocephalus*, *Parillaenus*, *Phorocephala*, *Prionocheilus*, *Prosopiscus*, *Pseudosphaerexochus*, *Rhombampyx*, *Sinocybele*, *Telephina*

8-2: *Agerina*, *Alceste*, *Amphitryon*, *Ampyx*, *Ampyxinella*, *Aspidaeglina*, *Birmanites*, *Calymenesun*, *Cekovia*, *Corrugatagnostus*, *Cyamella*, *Cyclopyge*, *Decoroproetus*, *Degamella*, *Diacanthaspis*, *Dionide*, *Dionidella* (*Huangnigangia*), *Dislobosaspis*, *Dubhglasina*, *Effnaspis*, *Ellipsotaphrus*, *Elongatanileus*, *Encrinurella*, *Gastropolus*, *Girvanopyge*, *Hanjiangaspis*, *Hexacopyge*, *Holdenia*, *Jianxilithus*, *Lamproscutellum*, *Leiagnostus*, *Lichas*, *Lisogolites*, *Lonchodomas*, *Madygenia*, *Megatemnoura*, *Miaopopsis*, *Microparia* (*Microparia*), *Microparia* (*Quadratapyge*), *Nanillaenus*, *Nileus*, *Niuchangella*, *Oedicybele*, *Ogmasaphus*, *Ovalocephalus*, *Panderia*, *Paraphillipsinella*, *Parillaenus*, *Parisoceraurus*, *Pentacopyge*, *Phillipsinella*, *Phorocephala*, *Placoparia*, *Platytychopyge*, *Pricyclopyge*, *Pseudampyxina*, *Pseudopetigurus*,

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*Pseudosphaerexochus, Psilacella, Quyuania, Reedocalymene, Remopleurides, Rhombampyx, Rorringtonia, Sagavia, Sarkia, Shumardia, Sinocybele, Sphaeragnostus, Sphaerexochus, Spinillaenus, Stenoblepharum, Stenopareia, Symphysops, Taklamakania, Telephina, Trinodus, Xenocyclopyge, Xiushuilithus*

### Mid-late Darriwilian (Llanvirn)

4-2: *Amphitryon, Birmanites, Endymionia, Gog, Illaenus, Liomegalaspides, Mendolaspis, Mioptychopyge, Nanillaenus, Nanshanaspis, Nileus, Ogmasaphus, Ovalocephalus, Pseudocalymene, Rhombampyx, Shumardia, Taklamakania, Tarimella, Telephina, Yanhaoia, Zhenganites*

5-1: *Ampyx, Basilicus (Basilicus), Basilicus (Basiliella), Basilicus (Parabasilicus), Glaphurina, Lamproscutellum, Lonchobasilicus, Pliomerina, Sphaerexochus*

5-2: *Abulbaspis, Basilicus (Basiliella), Birmanites, Conophrys, Dulanaspis, Endymionia, Nileus, Ovalocephalus, Paraptychopyge, Poronileus*

5-4: *Ampyxinella, Basilicus (Basilicus), Basilicus (Basiliella), Elongatanileus, Geragnostus, Hemiarges, Illaenus, Leiagnostus, Lonchobasilicus, Lonchodomas, Mendolaspis, Nanshanaspis, Nileus, Ovalocephalus, Paradionide, Plasiaspis, Pliomerina, Poronileus, Porterfieldia, Prosopiscus, Rhombampyx, Shumardia, Symphysurus, Taklamakania, Tarimella, Telephina, Toernquistia*

8-1: *Agerina, Amphilichas, Ampyx, Annamitella, Birmanites, Bumastoides, Calymenesun, Calymenia, Diacanthaspis, Dicranurus, Hexacopyge, Illaenus, Lonchodomas, Metopolichas, Neseuretus, Ovalocephalus, Parillaenus, Phorocephala, Prionocheilus, Prosopiscus, Pseudosphaerexochus, Rhombampyx, Sinocybele, Telephina, Vietnamia*

8-2: *Agerina, Ampyx, Bathycheilus, Birmanites, Calymenesun, Carolinites, Cyamella, Cyclopyge, Dionide, Gog, Hemisphaerocoryphe, Hexacopyge, Illaenus, Leiagnostus, Liomegalaspides, Lonchodomas, Megatemnoura, Miaopopsis, Microparia (Microparia), Microparia (Quadratapyge), Mioptychopyge, Nanillaenus, Nileus, Ogmasaphus, Ovalocephalus, Panderia, Paraphillipsinella, Paratiresias, Parillaenus, Parisoceraurus, Platyptychopyge, Pricyclopyge, Prionocheilus, Pseudocalymene, Pseudopetiguris, Pseudosphaerexochus, Pytine, Reedocalymene, Rhombampyx, Rorringtonia, Sagavia, Sinocybele, Spinillaenus, Stenoblepharum, Stenopareia, Telephina, Trinodus, Yanhaoia, Zhenganites*

### Floian-early Darriwilian (Arenig)

4-1: *Liomegalaspides*

4-2: *Birmanites, Carolinites, Eccoptochile, Hemisphaerocoryphe, Illaenus, Liomegalaspides, Mioptychopyge, Nanillaenus, Nileus, Ogmasaphus, Ovalocephalus, Pseudocalymene, Yanhaoia, Zhenganites*

5-1: *Basilicus (Basilicus), Basilicus (Basiliella), Basilicus (Parabasilicus), Eoisotelus, Illaenus, Pliomerina*

5-2: *Abulbaspis, Annamitella, Basilicus (Basiliella), Geragnostus, Glaphurina, Gog, Lonchodomas, Mendolaspis, Phorocephala, Placoparina, Poronileus, Pytine, Tongxinaspis*

5-4: *Annamitella, Basilicus (Basiliella), Cybelopsis, Geragnostus, Homalopyge, Illaenus, Omuliovia, Porterfieldia, Rhombampyx, Scotoharpes, Tsaidamaspis*

8-1: *Agerina, Ampyx, Carolinites, Ceratolithus, Chengkouella, Fenghuangchengia, Geragnostus, Guizhouhystricurus, Guizhoupliomeros, Hagiorites, Hanchungolithus, Hungioides, Liomegalaspides, Madygenia, Meitanopsis, Metopolichas, Mioptychopyge, Neopsilocephalina, Neseuretus, Ningkianites, Ningkianolithus, Niobella, Omeipsis, Omuliovia, Ovalocephalus, Phorocephala, Pseudocalymene, Psilocephalina, Psilocephalops, Rhombampyx, Saltaspis, Scotoharpes, Taihungshania, Yinpanolithus*



8-2: *Agerina*, *Ampyx*, *Alloillaenus*, *Annamitella*, *Aristocalymene*, *Aulacopleura* (*Paraaulacopleura*), *Birmanites*, *Caputrotundum*, *Carolinites*, *Celmus*, *Ceratocephalina*, *Cyclopyge*, *Degamella*, *Diacanthaspis*, *Dikelocephalina*, *Dionide*, *Eccoptychile*, *Euloma*, *Geragnostus*, *Gog*, *Han*, *Hanchungolithus*, *Hemisphaerocoryphe*, *Hexacopyge*, *Hungioides*, *Illaeus*, *Incaia*, *Liomegalaspides*, *Loganopeltis*, *Madygenia*, *Microparia* (*Microparia*), *Microparia* (*Quadratapyge*), *Mioptychopyge*, *Nanillaenus*, *Neseuretus*, *Nileus*, *Ningianites*, *Ningianolithus*, *Niobe*, *Niobella*, *Opipeuterella*, *Ovalocephalus*, *Paraphillipsinella*, *Paratiresias*, *Phorocephala*, *Pricyclopyge*, *Proscharyia*, *Prosopiscus*, *Pseudocalymene*, *Pseudopetigurus*, *Rhombampyx*, *Sagavia*, *Scotoharpes*, *Shumardia*, *Sinocybele*, *Symphysurus*, *Taihungshania*, *Toernquistia*, *Trinodus*, *Xystocrania*, *Yinpanolithus*, *Zhenganites*

### Tremadocian

4-1: *Aksuaspis*

4-2: *Acrocephalina*, *Asaphopsoides*, *Bienvillia*, *Borthaspidella*, *Diceratopyge*, *Dichelepyge*, *Dividuagnostus*, *Euloma*, *Harpides*, *Hysterolenus*, *Leiagnostus*, *Lotagnostus* (*Semagnostus*), *Macropyge*, *Niobella*, *Norinia*, *Platypeltoides* (*Troedssonina*), *Prospectatrix*, *Proteuloma*, *Pseudocalymene*, *Psilocephalina*, *Rhadinopleura*, *Scotoharpes*, *Shumardops*, *Trilobagnostus*, *Trinodus*

5-1: *Annamitella*, *Apatokephalops* (*Lulongia*), *Apatokephalus*, *Asaphellus*, *Asaphopsoides*, *Chosenia*, *Dikelocephalina*, *Hystricurus*, *Illaeus*, *Jiia*, *Jiliaoaspis*, *Jujuyaspis*, *Kainella*, *Kayseraspis*, *Koraipsis*, *Leiostegium* (*Euleiostegium*), *Leiostegium* (*Jinanaspis*), *Leiostegium* (*Leiostegium*), *Omuliovia*, *Parapilekia*, *Peltabellia*, *Penchiopsis*, *Platypeltoides* (*Troedssonina*), *Protopliomerops*, *Pseudorhaptagnostus*, *Remopleuridiella*, *Scotoharpes*, *Sinobathyurus*, *Songtaoia*, *Strigigenalis*, *Trilobagnostus*, *Wanliangtingia*, *Yosimuraspis*

5-4: *Bienvillia*, *Ceratopyge*, *Conophrys*, *Geragnostus*, *Harpides*, *Hystricurus*, *Kainella*, *Leiostegium* (*Leiostegium*), *Nileus*, *Omuliovia*, *Onychopyge*, *Parabolinella*, *Platypeltoides* (*Troedssonina*), *Pseudokainella* (*Pseudokainella*), *Symphysurus*, *Szechuanella*, *Yinaspis*

8-1: *Annamitella*, *Apatokephalops* (*Apatokephalops*), *Asaphellus*, *Asaphopsoides*, *Aulacopleura* (*Paraaulacopleura*), *Chashania*, *Chengkouella*, *Chosenia*, *Chungkingaspis*, *Conophrys*, *Dactylocephalus*, *Dikelocephalina*, *Geragnostus*, *Goniophrys*, *Guizhouhystricurus*, *Harpides*, *Hungioides*, *Hystricurus*, *Iduia*, *Illaeus*, *Jiia*, *Jinshaella*, *Lohanpopsis*, *Parapilekia*, *Pseudocalymene*, *Psilocephalina*, *Remopleuridiella*, *Scotoharpes*, *Songtaoia*, *Trinodus*, *Tungtzuella*, *Wanliangtingia*, *Yosimuraspis*

8-2: *Acrocephalina*, *Akoldinioidea*, *Amzasskiella*, *Anglagnostus*, *Apatokephalus*, *Asaphopsoides*, *Bienvillia*, *Birmanites*, *Brachyhipposiderus*, *Ceratopyge*, *Chosenia*, *Ciliocephalus*, *Clavatellus*, *Conophrys*, *Degamella*, *Diceratopyge*, *Dichelepyge*, *Dividuagnostus*, *Euloma*, *Geragnostus*, *Gymagnostus*, *Harpides*, *Hospes*, *Hunanopyge*, *Hypermeccaspis*, *Hysterolenus*, *Illaeopsis*, *Leiagnostus*, *Leiostegium* (*Leiostegium*), *Levisaspis*, *Liexiaspis*, *Lotagnostus* (*Semagnostus*), *Macropyge*, *Metayuepingia*, *Micragnostus*, *Niobe*, *Niobella*, *Onchonotellus*, *Onychopyge*, *Orometopus*, *Palaeoharpes*, *Parabolinella*, *Parapilekia*, *Pharostomina*, *Platypeltoides* (*Troedssonina*), *Proscharyia*, *Prospectatrix*, *Protarchaeogonus*, *Proteuloma*, *Protopliomerops*, *Pseudocalymene*, *Pseudokainella* (*Pseudokainella*), *Pseudokoldinioidea*, *Pseudorhaptagnostus*, *Rhadinopleura*, *Scotoharpes*, *Sinoparapilekia*, *Songtaoia*, *Strictagnostus*, *Symphysops*, *Szechuanella*, *Symphysurus*, *Taoyuania*, *Trilobagnostus*